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GEOLOGY OF WISCONSIN AND LOCATION AND PROPERTIES OF AGGREGRATES IN WISCONSIN

by

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If you could have arrived in Wisconsin about a half-billion years ago you would have found a plain with a few hills and ridges rising above a generally level surface. Just as the stump-covered field enables us to picture the forest that has long since disappeared, so a study of the worn-down stumps of mountains would have enabled us to reconstruct the mountains that once covered all of Wisconsin. At Madison, the old granite surface is now encountered at a depth of 800 feet; in the southeastern part of the state it is reached at a depth of over 1800 feet. In the southwestern part of the state, at Platteville, the ancient granite surface is 1700 feet below the surface. In Lee County, Illinois, about 60 miles south of the Wisconsin line, the pre-Cambrian surface is probably at a depth of 3,000 feet below sea level.

Shortly thereafter in the Cambrian period, much of the state was covered by a shallow sea. Only the Baraboo Range and other pre-Cambrian ridges in the southern part of the state, as well as some of the northern part of the state, stood above the water level.

For about a quarter of a billion years marine conditions persisted, with at least one period when the land rose above sea level and was subjected to weathering and erosion. In the sea, sediments were deposited -- sands, lime muds, and muds which were consolidated to become sandstones, limestones, and shales. Even the pre-Cambrian ridges were buried.

When the area was lifted above the sea, the series of beds over 2,000 feet in thickness was arched into a broad fold with the axis trending north and south. As a result, the beds dip gently eastward in the eastern part of the state, southward in the southern part, and westward in the western part, much like the shingles on a roof except that the butt edges of these shingles project up the roof. During and following the uplift the rocks were subjected to a long period of erosion during which enormous quantities of rock were worn away, so that none of the formations have as great an extent as formerly. Each formation in its recession left out-lying buttes and mesas which are like stragglers of a retreating army. Blue Mounds is an isolated outlier of the Niagara escarpment which is 70 miles to the east in Wisconsin, 45 - 55 miles to the south in Illinois and Iowa. The Platte Mounds and the sandstone mounds near Camp Douglas are of similar origin. Deep valleys were cut by streams. The Mississippi River flowed in a gorge nearly 800 feet in depth. There were no lakes.

Pre-Cambrian. The rocks at or near the surface in a great shield-shaped area in the northern part of the state and underlying younger rocks at depth in the rest of the state are granite, trap, sandstone and iron-formation.

Cambrian Sandstone and Shale. South of the older rocks is a crescentic belt of the Cambrian formation extending from Marinette County southwest through Adams and Juneau counties, thence northwest to Washburn County. This formation outcrops along the Wisconsin and Mississippi rivers. This formation, which in the outcrop area is about 700 feet thick, is made up in large measure of sandstone. There are three sandy shale members, the Eau Claire, Franconia and Lodi. In this belt embracing nearly one-fourth of the area of the state, the soil is sandy. The Cambrian extends beneath the younger formations and is the source of artesian water in the southern part of the state.

Lower Magnesian Dolomite. This formation extends as a somewhat broken crescent from Marinette County to Polk County. As this is a resistant rock, the butt edge forms a steep slope facing toward the central part of the state.

St. Peter Sandstone. Prior to the deposition of this sandstone, there was extensive erosion so that deep valleys were cut in the Lower Magnesian and even through it into the Cambrian. As a result, the formation varies greatly in thickness. Exposures are usually found in a narrow belt near the inner edge of the overlying Platteville (Trenton) dolomite. It may be seen as the steep wall near a valley floor or as isolated crags such as Monument Rock or Sylvan Rocks. In Wisconsin, this sandstone is locally used as a source of plastering sand and as ballast in highway construction. Much of the glass sand and considerable molding sand of Illinois comes from this formation. It is also the source of the Ottawa sand used in testing laboratories.

Galena-Platteville Formation. This is the rock underlying a belt 12 to 20 miles in width extending from Marinette to the state line in western Walworth County, forming the upland surface of the southwestern part of the state, and capping a few ridges farther north. The underlying member, Platteville (Trenton), consists of shale, limestone interbedded with shale and some thicker bedded dolomite. The Galena is the main ore-bearing formation of the lead and zinc district. It is a granular, well-bedded dolomite. Upon weathering, it breaks down into a coarse, yellow dolomite sand. Chert is in considerable quantity in the lower half of the formation.

Maquoketa Shale. This formation outcrops in a few places along the Niagara escarpment in the eastern part of the state. In southwestern Wisconsin it forms the long, gentle slopes of the mounds.

Niagara Dolomite. This formation underlies a broad belt in the eastern part of the state and caps Blue Mound and Platte Mound.

Devonian Formation. This formation borders Lake Michigan in a narrow belt extending from Sheboygan to the mouth of the Milwaukee River. There are but few outcrops.

Glacial Deposits. The last great event in the geological history was the coming of an ice sheet. The winters became not a great deal colder, but were longer so that the winter snows were not melted during the shorter summers. The ice moved away from centers east and west of Hudson Bay and occupied nearly all of the territory north of the Missouri and Ohio rivers. During the glacial period the ice advanced and retreated four times. During all of the glacial period the southwestern part of the state was not invaded by ice. There is, therefore, a Driftless Area which gives us an idea of what Wisconsin was like before the ice age.

Throughout the glaciated area the most important road material is gravel. By far the greater proportion of our gravel comes from outwash deposits. Nearly all of the large commercial plants are operating in outwash deposits. These are likely to prove uniform in character and dependable in extent. In a terminal moraine the following are favorable sites for search: (a) long, narrow, steep-sided ridges relatively free from large boulders; (b) cone-shaped hills. Terminal moraines are likely to be a much less satisfactory source of gravel than outwash. Eskers are usually long, narrow, winding ridges occurring in level country, often in swamps. The material is likely to be pockety in character, with bedding and size of material erratic. Beach gravel is valuable largely because it is found in areas where other gravel is scarce as in Douglas, Bayfield, Ashland, and Iron counties.

COARSE CONCRETE AGGREGATES

Wisconsin is the fortunate possessor of excellent concrete aggregates fairly well distributed throughout the state. These are either quarry stone or gravel. In discussing coarse aggregates, reference will be made to per cent of wear, absorption and specific gravity. By wear is meant the per cent loss by weight through a No. 12 screen in 500 revolutions of the Los Angeles machine. In general, the absorption is higher and the specific gravity is lower for rock with a high per cent of wear.

Quarry Stone. Such stone may be either one of the crystalline types or limestone.

Crystalline Rocks. Granite or basalt (trap) make excellent aggregates, but cost of quarrying and crushing prohibits their use in areas where gravel is available. Very few tests are available. In these the wear ranges from 11.1 to 27 per cent, the absorption, .26 to 2.65 per cent, and the specific gravity, 2.72 to 2.94. Quartzite has not been used as an aggregate because crushing produces too large a proportion of flat and elongated pieces.

Limestone. Strictly speaking, these rocks are dolomites, but for our purposes the use of the commonly used "limestone" seems desirable. Tests from four formations are available: Niagara, Galena, Trenton and Lower Magnesian. Limestone quarries from any formation should be carefully inspected. Aside from laboratory tests, the best check on the quality of stone is made by an inspection of an older part of the quarry or in outcrops where the face has been exposed to weathering.

The Niagara dolomite which reaches a maximum thickness of 800 feet is subject to the same variations laterally and vertically as are all limestones. The wear of rock from five quarries ranged from 25.1 to 28.4 per cent; the absorption from .69 to 2.45 per cent; and the specific gravity from 2.60 to 2.70. This formation has not been used to any extent as concrete aggregate because in much of the outcrop area there is an adequate supply of limestone gravel. It is an excellent source of concrete aggregate in any area where it occupies a competitive position, if care is exercised in selecting quarry sites.

The Galena limestone in many outcrops and quarries is weathered to the extent that it cannot be considered as concrete aggregate. Samples from a few of the better quarries show a wear test of 33.3 to 42.5; absorption, 1.06 to 3.45, and specific gravity, 2.55 to 2.71.

The Trenton formation consists of shale, limestone interbedded with shale, and some quarry beds. While quarries can produce stone with a percentage of wear less than 50, the absorption is high and specific gravity low. Service experience as well as laboratory soundness tests have shown that this formation should not be used as a concrete aggregate.

The Lower Magnesian limestone. This formation is an important potential source of concrete aggregate in much of the Driftless Area. Any consideration of a quarry site in this formation should take into account the variations in quality from bed to bed. It must also be recalled that the formation was deeply eroded prior to the deposition of the St. Peter sandstone. In some places the Lower Magnesian is entirely missing. Following is a description of the formation beginning at the top:

Ledge or Crag Forming Beds. 65 to 100 feet in thickness. Thick, massive bedded, cavernous weathering limestone underlain by heavy chert bed. Rock is hard and tough. Some chert present. Good material.

Quarry Beds. 25 - 35 feet in thickness. Buff, fairly soft and weak, granular, even-textured rock. In general, too soft for use as road material. Called punky bed.

Basal Beds. Thickness up to 25 feet. Dense, fairly hard and tough, fine-grained or granular rock. The lower part is in many places weak and cherty.

Transition Beds. 25 - 30 feet in thickness. A transition from the Jordan below to the dense limestone above. It consists of thin beds of sandstone, thin dense limestone, algal chert layers, thin green speckled beds.

From the above it may be seen that but two phases of the formation are worth serious consideration, the basal beds and the upper ledge forming beds. Even these must be inspected to determine whether an objectionable percentage of chert is present. Large-scale development is hampered in some quarries by the presence of clay pockets.

Of 21 laboratory tests the wear ranges from 25.6 to 49.9, the absorption, 17 to 3.6, and the specific gravity from 2.45 to 2.72. In general, low absorption and high specific gravity is associated with low wear.

Gravel. The rock content of gravel may be classified as crystalline or limestone. The crystalline consists largely of granite, trap and other igneous and metamorphic rock; the limestone gravel consists of a large percentage of limestone pebbles. Of course, there are all gradations between the two extremes. In general, the gravel in the Pre-Cambrian areas is crystalline. Gravel derived from limestone areas usually carries a high percentage of limestone.

The crystalline gravels have a low wear, the range in nine samples being from 17.3 to 23. The absorption is also low, ranging from .32 to 1.34. The specific gravity is high, ranging from 2.59 to 2.77. These gravels have given good service in concrete.

Limestone gravels have a somewhat higher per cent of wear, in 14 samples ranging from 25.2 to 40.4. Gravels derived from the Niagara formation have a lower wear than those from the Galena and Trenton. The absorption ranges from .64 to 3.00, the lower values coming from the Niagara. The specific gravity ranges from 2.51 to 2.74, the higher values also coming from Niagara sources.

Deleterious substances in Wisconsin gravels are not as serious a problem as in some of the neighboring states. Although the glacier moved over the Maquoketa shale, this material did not stand transportation. There is no coal in Wisconsin; hence there is no coal in our gravels. In a few places where there was a readvance of the ice over lake clays there are clay balls in the gravel, but this is not a common difficulty. In both cyrstalline and limestone gravels there is some weathered rock, usually not as much as 5 per cent. Soft friable sandstone rules out the use of some gravel. Chert is a problem in some areas, especially where the gravel is derived from the Galena formation.

TRAP ROCK

	Wear	Absorption	Specific Gravity
Dresser Jct., Polk Co.	11.1	0.41	2.94
Douglas Co., Sec. 13, T.47N., R.13W.	18.9	2.65	2.72
Mellen, Ashland	27.0	.26	2.91

LIMESTONE QUARRIES

Niagara Formation

	Wear	Absorption	Specific Gravity
Lannon, Waukesha Co.	25.1	.93	2.70
Sturgeon Bay	28.1	.69	2.78
Ives, Racine	28.4	1.22	2.63
Francey, Milwaukee	28.4	2.45	2.60
Waukesha Lime and Stone	26.0	1.71	2.69

Galena Formation

	Wear	Absorption	Specific Gravity
Lutz Stone Co., Oshkosh	39.0	1.56	2.71
Lutz Stone Co., Oshkosh	33.7	1.06	2.75
Kieler, Loc. 100, Grant Co.	33.3	1.46	2.69
Watson, SE SE sec. 3, T.6N., R.5E.	42.5	3.45	2.55
1 1/3 mi. E. of Elmo, Lafayette Co.	54.0	3.3	2.54 (chert)
W. Calvert, SW$\frac{1}{4}$ sec. 3, T.3N., R.3E.	41.0	1.7	2.64
Duck Creek, Brown Co.	22.9	.86	2.77

Trenton Formation

	Wear	Absorption	Specific Gravity
Anding, Loc. 184, St. Croix Co.	35.3	3.57	2.53
Severson, Green Co.	39.1	2.45	2.58
Loc. 70, Green Co.	44.3	3.02	2.61
Taylor, Rock Co.	44.4	2.54	2.61

Lower Magnesian Formation

	Wear	Absorption	Specific Gravity
Gallagher and Nelson, Dane Co.	43.5	3.7	2.55
Pronold, Iowa Co.	41.0	2.4	2.60
Rawson, Loc. 16, Richland Co.	47.0	2.20	2.62
Schueknecht, Loc. 254, Sauk Co.	38.0	2.2	2.62
Meyer, Sauk Co.	38.0	2.03	2.61
Watson, Loc. 96, Vernon Co.	30.0	2.66	2.58
Bakkestrien, Loc. 30, Vernon Co.	45.0	2.7	2.57
Upper 47' better than lower 28			
Heal, Vernon Co.	39.0	1.8	2.67
Loc. 125, Vernon Co.	35.6	.98	2.72
Loc. 131, Vernon Co.	36.3	1.31	2.66
Pokrandt, Loc. 114, Marquette Co.	30.3	1.35	2.72
Chimney Rock, Loc. 216, Trempealeau Co.	49.9	2.84	2.61

(Cont.)

Lower Magnesian Formation (Cont.)

	Wear	Absorption	Specific Gravity
Loc. 63, Trempealeau Co.			
Upper 24'	43.0	2.2	2.60
Lower 24'	49.0	3.5	2.45
Herman Pape, Loc. 70, Buffalo Co.	44.0	2.8	2.56
Loc. 50, Buffalo Co.	30.8	1.22	2.70
Hoffman-Haglund, NE$\frac{1}{4}$ sec. 5, T.24N., R.15W. & SE$\frac{1}{4}$ sec. 32, T.25N., R.15W., Pierce Co.	47.0	2.6	2.59
West Plum City Hill, center 16, T.25N., R.15W., Pierce Co.	48.0	3.6	2.53
Elmwood, Pierce Co.	47.2	3.01	2.53
Wilson, St. Croix Co.	43.8	3.08	2.54
Loc. 33, St. Croix Co.	25.6	.70	2.75

GRAVEL AGGREGATES

Limestone

	Wear	Absorption	Specific Gravity
Pound, Loc. 128, Marinette Co.	27.3	1.09	2.71
Maribel, Loc. 86, Manitowoc Co.	28.2	1.34	2.70
Palmer-Slinger, Loc. 8, Washington Co.	33.5	.88	2.74
Barton, Washington Co.	30.6	.98	2.74
Loc. 42, Fond du Lac Co.	31.5	.64	2.79
Racine Co., SW$\frac{1}{4}$ sec. 6, T.2N., R.19E.	25.2	1.29	2.68
Bellman, SE NE sec. 20, T.3N., R.15E., Walworth Co.	30.1	1.29	2.68
Janesville Sand and Gravel Co.	37.0	1.58	2.64
Edgerton, Rock Co.	35.5	2.29	2.58
Capitol Sand and Gravel Co.	40.0	1.56	2.71
Loc. 280, Dane Co.	36.1	1.56	2.61
Verona, Dane Co.	39.3	3.00	2.51
Patchin, Loc. 116, Columbia Co.		1.59	2.68
Loc. 26, Green Co.	40.4	2.82	2.51

Crystalline

	Wear	Absorption	Specific Gravity
Eau Claire Sand and Gravel Co., Chippewa Falls		.32	2.65
Wausau Sand and Gravel Co.		.4	2.69
Wissota Sand and Gravel Co.	20.2	1.34	2.68
Stoner Gravel Pit, Barron Co.	23.	1.6	2.66
Loc. 54, Clark Co.	19.		
Eau Claire Sand and Gravel Co., Shawtown	23.5	1.24	2.67
Loc. 19, Polk Co.	17.3	.84	2.70
Loc. 16, Polk Co.	19.4	.74	2.76
Loc. 56, Clark Co.	19.4	1.05	2.77
Hatfield, Jackson Co.	22.2	1.13	2.59
Loc. 37, Marinette Co.	22.5	.54	2.68
Mountain, Loc. 43, Oconto Co.	22.3	.50	2.71
Patzau, Douglas Co.	27.7	1.94	2.65